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Coupled Processes Workshop

Common words in presentations

- **Heterogeneity**
- **Limited number of samples**
- **Nonlinear processes**
- **Coupled processes**
- **Uncertainty**



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***What remains certain in
studying coupled processes?***

Uncertainty

Why?

- **Aleatoric uncertainty**, based on averaging parameters characterizing the subsurface and coupled processes
- **Epistemic uncertainty**, based on the lack of knowledge of media parameters and processes
- Uncertainty reducible and irreducible

Why?

- **Aleatoric uncertainty**, based on averaging parameters characterizing the subsurface and coupled processes
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- **Nonlinearity of processes**
- **Sensitivity to initial conditions**
- **Superposition of at least two nonlinear processes leads to fluctuations of the variables characterizing the process**
- **Coupled processes are deterministic-chaotic**



What?

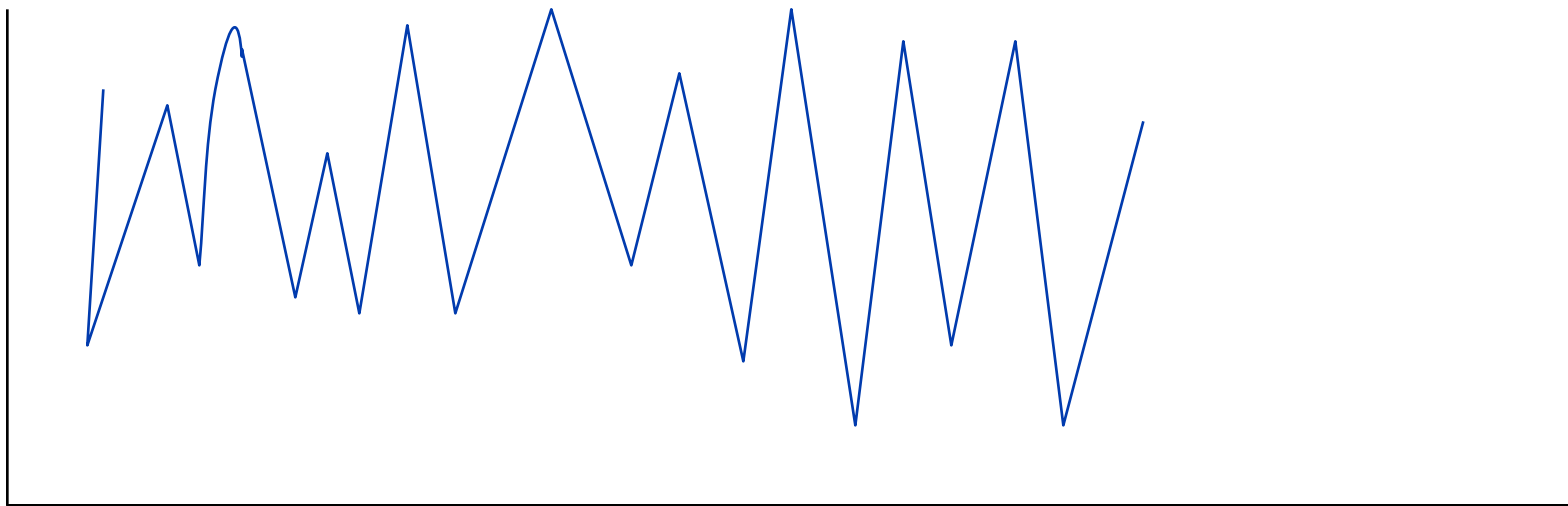
$$\frac{\partial C_1}{\partial t} = \square\square_1 C_1 \square a C_1 C_2$$

$$\frac{\partial C_2}{\partial t} = \square\square_2 C_2 \square b C_1^2$$

A simple system of two nonlinear equations will generate chaotic behavior



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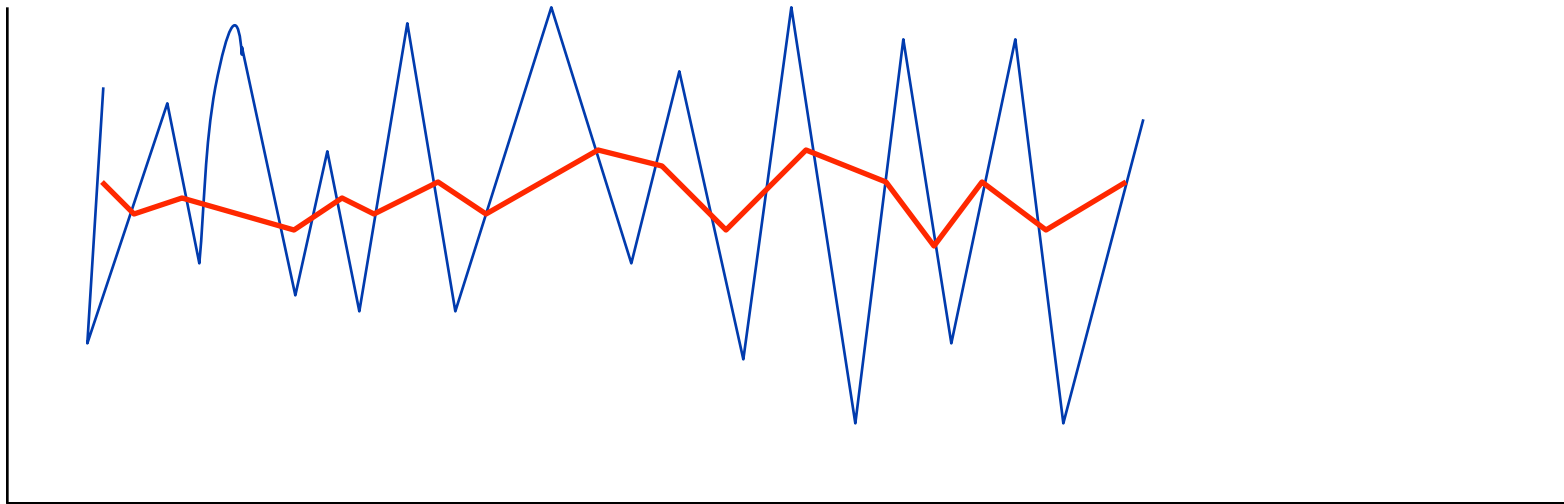


Time or distance



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Real fluctuations shown by a blue line cannot be detected using measurements shown by a red line



Time or distance



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What to do?

- **Study processes on different scales**
- **Because conventional scaling has a limited application for coupled processes:**
 - **Use different conceptual, mathematical and numerical models to simulate processes on different scales**
 - **Combine (aggregate) the results of measurements and predictions on different scales using a hierarchy approach**

How to do?



- A key issue is the correspondence between the types of measurements and models used simulate coupled processes